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NAVIER-STOKES CALCULATION OF TRANSONIC FLOW PAST THE NTF 65-DEGREE DELTA WING

by

Professor Chivey Wu
Department of Mechanical Engineering
California State University
Los Angeles, CA 90032

Abstract

This project is a continuation of the research initiated in summer last year. Viscous flow past a wind tunnel model of a 65-degree swept angle Delta wing at transonic speeds is being studied. The model was tested in the 8-foot cryogenic transonic wind tunnel at the National Transonic Facility. Aerodynamic forces and wing surface pressure data were obtained at various angles of attack, Mach numbers and Reynold's numbers for four different leading edges of the wing. The objectives of the present investigation are:

1. To perform numerical modelling of the flow around the wing.
2. To validate the experimental data with a Navier-Stokes computational fluid dynamics code and vice versa.
3. To investigate the effects of the sting mount of the wing.
4. To evaluate the effects of leading edge radius on the flow.
5. To explain the Reynold's number effect as indicated by the test data.

Several computer programs were developed to define the surfaces of the wing, the four leading edges and the sting mount. Based on these geometric databases, the surface grids of a single-block computational domain was generated interactively on the IRIS workstation using the GRIDGEN2D module of GRIDGEN. To refine the grids and to avoid excessive loss of grid points due to collapsed edges, a 9-block computational domain containing approximately 750,000 grid points was developed with the GRIDBLOCK module to replace the single-block grid:

<u>Block No.</u>	<u>Model Surface Contained</u>	<u>Dimension</u>
1	Fore Upper Wing	49x13x65
2	Leading Edge	49x49x65
3	Fore Lower Wing	49x13x65
4	Sting	49x49x65
5	Wing Apex	25x25x65
6	Upper Sting Joint	49x25x65
7	Rear Upper Wing	49x25x65
8	Rear Lower Wing	49x25x65
9	Lower Sting Joint	49x25x65

Fig. 1 shows the wing and sting surfaces, and the block edges near the model, while Fig. 2 shows all the blocks in the entire computational domain encompassing a space of 20 chord lengths from the wing in all directions.

The double-precision version of GRIDGEN2D was then used to generate the surface grids of every block. Grid point-clustering was performed on high-curvature portions of the apex, the leading edge, the trailing edge and the sting joint. To facilitate thin-layer Navier-Stokes calculation at high Reynold's numbers, a very tight spacing of 10^{-6} was specified on the wing surface. Fig. 3 shows some typical surface grids on the model and the plane of symmetry. Figs. 4 and 5 show some typical 2-D grids on block interfaces. Upon minor modification of the blocks containing the wing apex and the leading edge, the surface grids of these two blocks can be generated for other leading edge profiles without disturbing the other blocks.

Job files and input files were created to read the multiple-block surface grids into the GRIDGEN3D module on the Cray super-computer to generate the internal volume grid of each block. A typical output file summarizing successful generation of satisfactory volume grids is given in Appendix A. The resulting volume grids were finally examined by the GRIDVUE3D module or the FAST software on the IRIS workstation.

The CFL3D computational fluid dynamics code, developed by the Computational Aerodynamics Branch, is to be applied. A typical input file which sets up the code to read the volume grids and specifies the boundary conditions for each block is given in Appendix B. Calculations for both laminar and turbulent flows are being conducted, and preliminary solutions are expected in the immediate future.

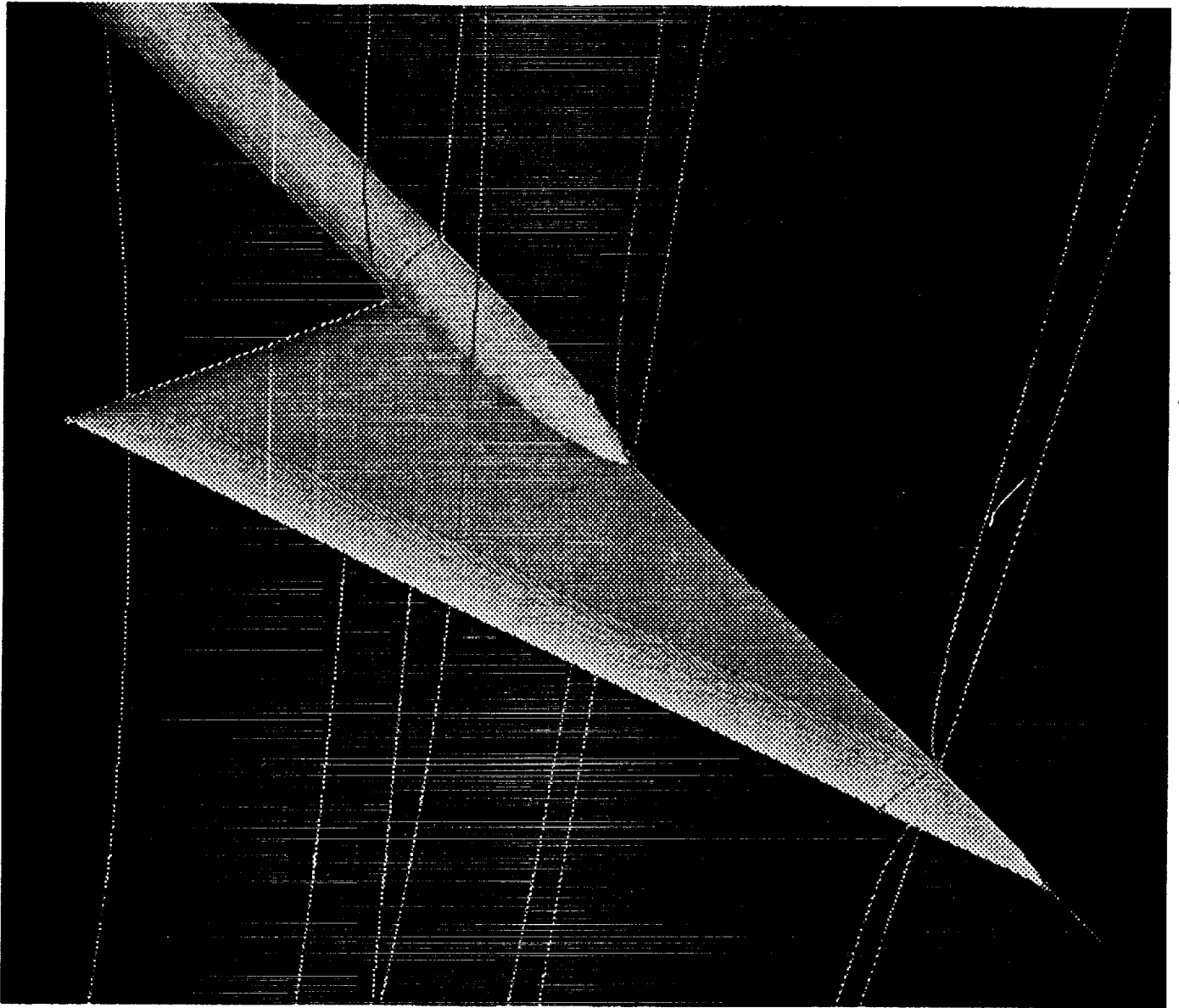


Fig. 1 Wing Model and Block Edges - Near Field



Fig. 2 Block Edges - Far Field

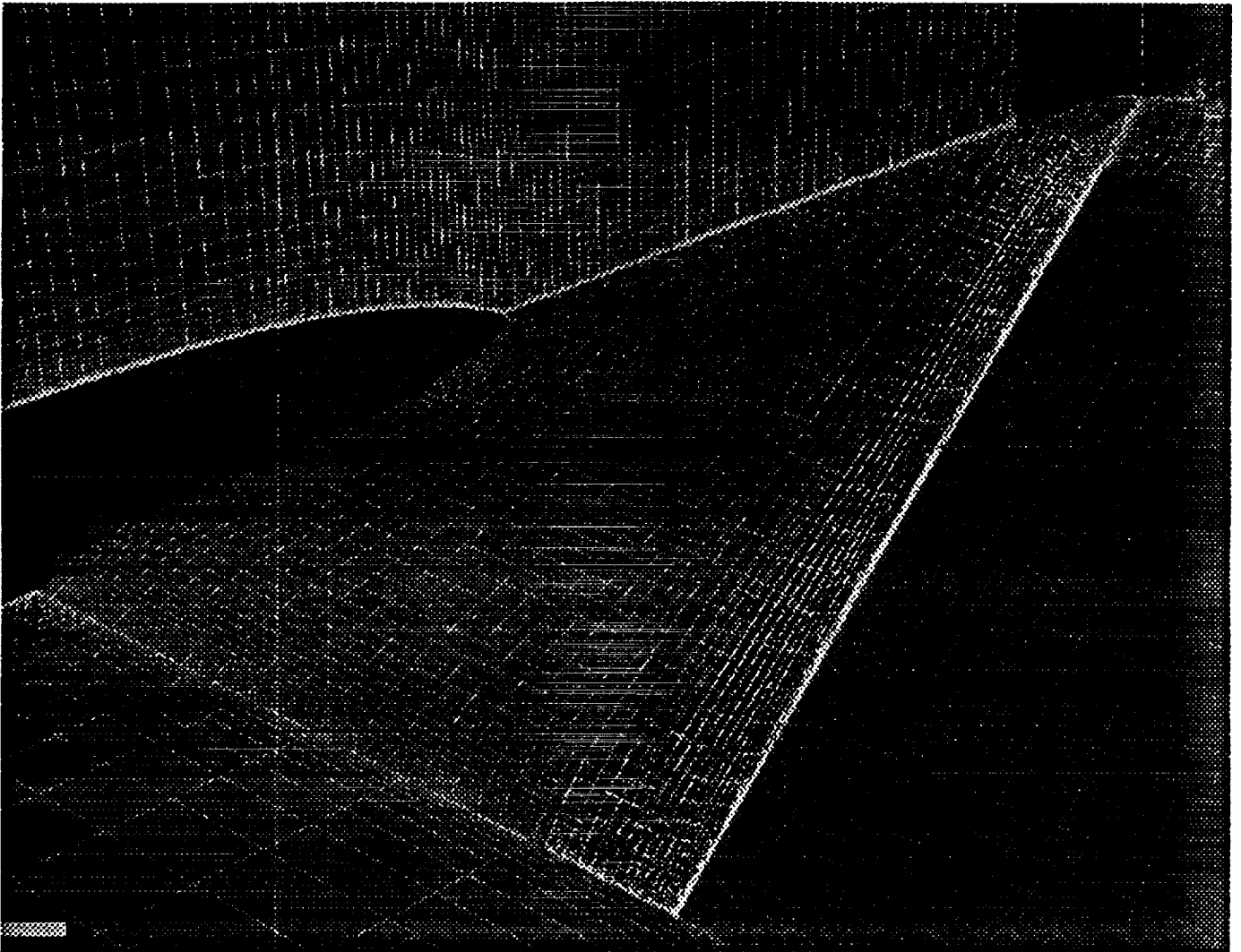


Fig. 3 Surface Grids on the Model and Plane of Symmetry

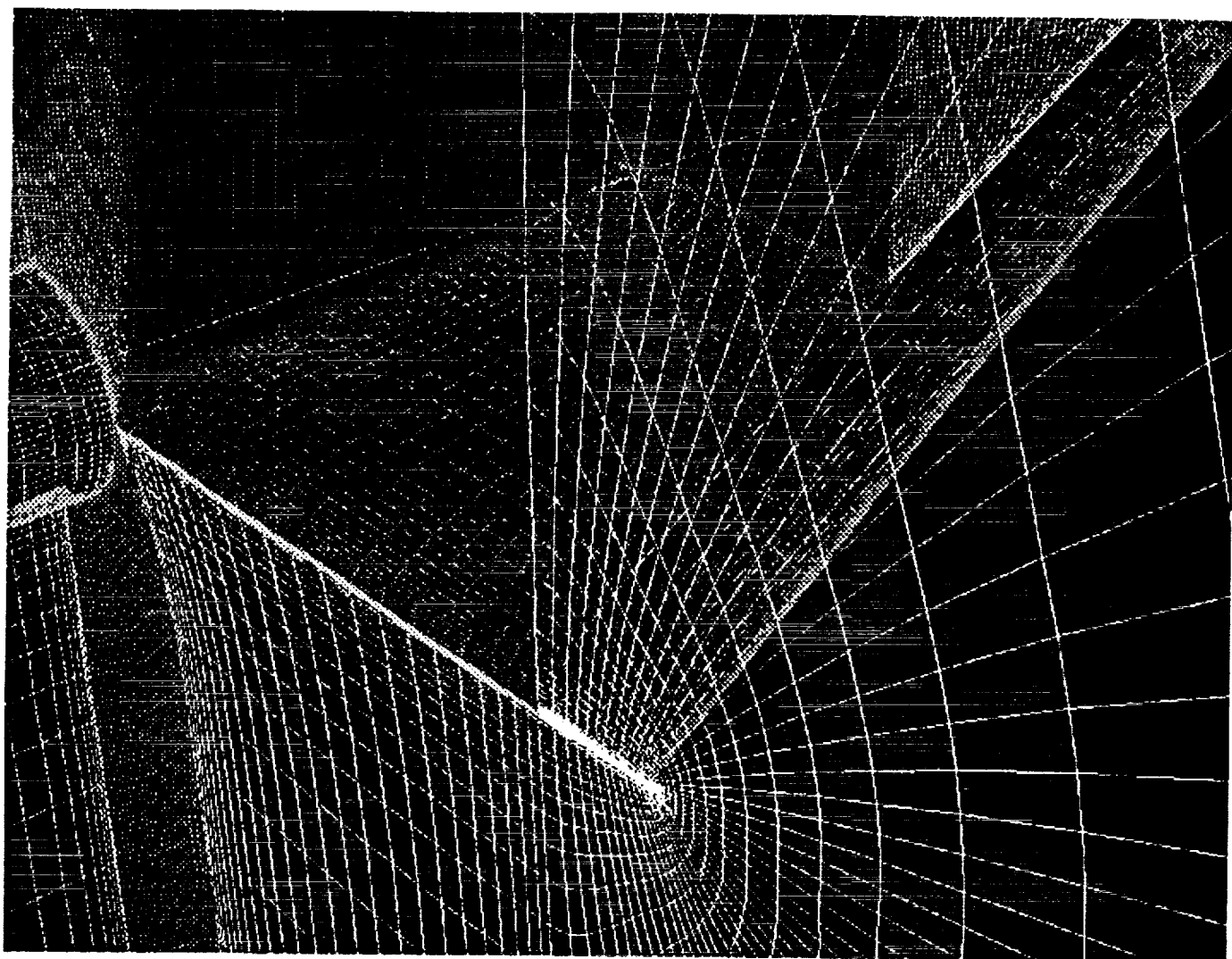


Fig. 4 Surface Grids on Block Interfaces

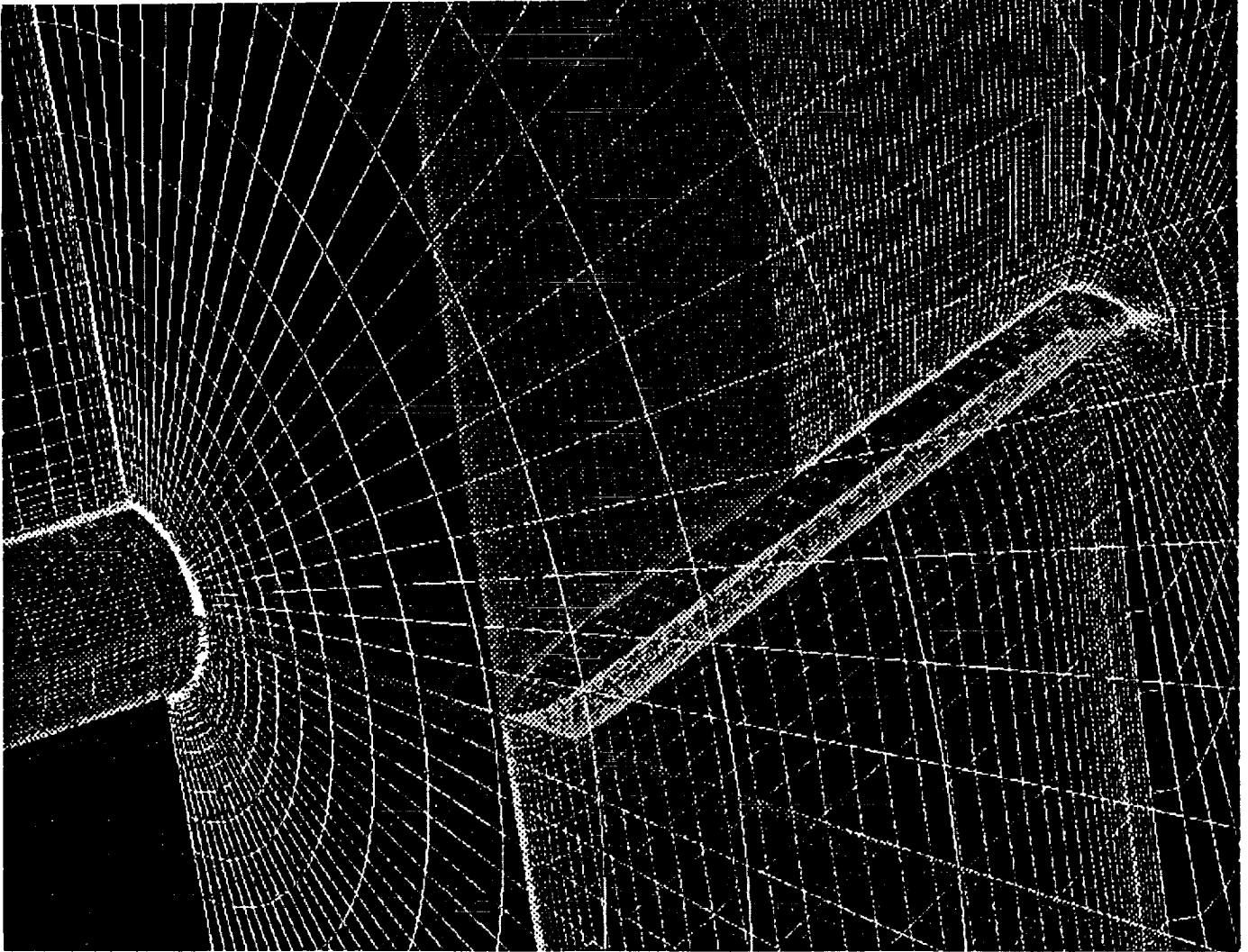


Fig. 5 Surface Grids on Block Interfaces

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number of negative volumes : 0 ( 0.00%)
minimum volume at ( 49, 2, 25) is 0.1773E-14
maximum volume at ( 25, 65, 25) is 0.1046E+00
-----
Jacobians for block # 3: inter4.blk
number of positive volumes : 36864 (100.00%)
number of skewed volumes : 0 ( 0.00%)
number of negative volumes : 0 ( 0.00%)
minimum volume at ( 2, 2, 13) is 0.8873E-12
maximum volume at ( 17, 65, 7) is 0.6504E-01
-----
Jacobians for block # 4: inter7.blk
number of positive volumes : 147456 (100.00%)
number of skewed volumes : 0 ( 0.00%)
number of negative volumes : 0 ( 0.00%)
minimum volume at ( 2, 2, 4) is 0.4317E-11
maximum volume at ( 49, 65, 47) is 0.2896E+02
-----
Jacobians for block # 5: inter1.blk
number of positive volumes : 36337 ( 98.57%)
number of skewed volumes : 527 ( 1.43%)
number of negative volumes : 0 ( 0.00%)
minimum volume at ( 2, 2, 13) is 0.1768E-13
maximum volume at ( 25, 65, 2) is 0.1002E+02
-----
Jacobians for block # 6: upjdnlt
number of positive volumes : 73728 (100.00%)
number of skewed volumes : 0 ( 0.00%)
number of negative volumes : 0 ( 0.00%)
minimum volume at ( 2, 2, 2) is 0.5358E-12
maximum volume at ( 31, 65, 25) is 0.2172E-01
-----
Jacobians for block # 7: wingup
number of positive volumes : 73728 (100.00%)
number of skewed volumes : 0 ( 0.00%)
number of negative volumes : 0 ( 0.00%)
minimum volume at ( 49, 2, 25) is 0.2289E-11
maximum volume at ( 29, 65, 2) is 0.2060E-01
-----
Jacobians for block # 8: winglo
number of positive volumes : 73728 (100.00%)
number of skewed volumes : 0 ( 0.00%)
number of negative volumes : 0 ( 0.00%)
minimum volume at ( 49, 2, 2) is 0.2181E-11
maximum volume at ( 29, 65, 16) is 0.2763E-01
-----
Jacobians for block # 9: jointclo
number of positive volumes : 73728 (100.00%)
number of skewed volumes : 0 ( 0.00%)
number of negative volumes : 0 ( 0.00%)
minimum volume at ( 2, 2, 25) is 0.4156E-12
maximum volume at ( 19, 65, 25) is 0.1394E-01
-----
Jacobian summary for entire grid

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```

GGGGG RRRRR I DDDDD GGGGG EEEEE N N 33333 DDDDD
G R R I D D G E NM N 3 D D
G GGG RRRRR I D D G GGG EEEEE N N N 33333 D D D
G G R R I D D G G E NM N 3 D D
GGGGG R R I DDDDD GGGGG EEEEE N N 33333 DDDDD

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*****
I N P U T
*****
LASSER LASSEN = 0, IDESG = 0, IFORN = 1, NOBLOCKS = 0, NBLOCKS = 9, NMI
2*49, 65, 13, 49, 65, 49, 25, 65, 25, 49, 65, 25, 49, 65, 25, 49, 65
IAUTO = 0, ISPW = 7009149136318496768, FNDOCI = 'interle4.bnda', FNSUR
FNOLI = 'interle4.vol', PATETMP = ''
-----
Grid contains 9 block(s)
-----
nb lmax jmax kmax name
1 49 65 13 inter2.blk
2 49 65 49 inter3.blk
3 49 65 13 inter4.blk
4 49 65 49 inter7.blk
5 25 65 25 inter1.blk
6 49 65 25 upjoint
7 49 65 25 wingup
8 49 65 25 winglo
9 49 65 25 jointclo
-----
*****
ALGEBRAIC SOLVER
*****
$INIT INITIAL = 9*2, TOLER = 1.E-9, ITSONI = 16, IJACA = 1 $END
-----
Jacobians for block # 1: inter2.blk
number of positive volumes : 36864 (100.00%)
number of skewed volumes : 0 ( 0.00%)
number of negative volumes : 0 ( 0.00%)
minimum volume at ( 2, 2, 13) is 0.5158E-12
maximum volume at ( 17, 65, 7) is 0.8509E-01
-----
Jacobians for block # 2: inter3.blk
number of positive volumes : 147456 (100.00%)
number of skewed volumes : 1 ( 0.00%)

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